/LIVE ANIMAL EVALUATION OF CARCASS TRAITS FOR SWINE AND SHEEP USING REAL-TIME ULTRASOUND/

by

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INTRODUCTION

One of the major deterrents to improving the carcass value of cattle, sheep and swine is a lack of accurate methods for measuring carcass traits in the live animal. The purpose of measuring the carcass traits on living animals evolves around animal breeding. That is, the selection and mating of individuals in order to make the greatest genetic progress.

The components of primary interest are those that provide us with an indication of the composition of the dressed carcass for economic evaluation such as the amount and distribution of fat and lean. The consumer is the one that must be satisfied in the production of meat animals. In today's health conscious society, it is desirable to have heavily muscled animals with only the minimal amount of fat needed to provide the palatability factors associated with the eating qualities that the consumer desires in a meat product.

While there have been many techniques applied to evaluate the composition of live animals, none have been ideal. Hedrick (1983) provided a good review of methods used in estimating live animal and carcass composition-their usefulness and problems associated with the various methods. For this reason, details pertaining to each method will not be presented. However, each one has made

some contribution to our knowledge of predicting carcass leanness. Several of the important procedures used to evaluate the live animal include ruler probe techniques, x-ray observations, measurements of inherent radioactivity, dye and isotope dilution techniques. Additional procedures which have been employed in the evaluation of live animal composition include creatinine determination, photogammetry and various external linear measurements. Several subjective appraisal methods have also been used in live animal evaluation. Complete physical dissection of the entire carcass has provided the most accurate determination of carcass composition. However, this is costly and not very practical and research has been undertaken to find simple measurements that provide an accurate indicator of composition.

The use of ultrasonics to determine density boundaries without tissue destruction was first reported by Wild (1950). Later, Wild and Neal (1951) demonstrated that the interface between muscle and fat could be determined in live cattle. After these reports, the application for live animal evaluation was reported both in Europe and in the United States at about the same time.

Numerous researchers have used the longissimus muscle area and quantity of fat in the lumbar thoracic region as indices of animal composition. The area of the longissimus muscle is considered highly heritable in meat

animals and if measured in the live animal would provide an additional aid in selecting superior breeding animals.

The ultrasonic technique provides a means of quantitative identification of muscle and fatty tissue of the live animal. This method is non-destructive and humane. Estimation of live animal composition from ultrasonic technique has been in existence for many years, however, the technology and quality of ultrasonic equipment now available has advanced dramatically in recent years. An understanding of the basic principles of sound propagation and interaction with body parts is required for a general understanding of ultrasound use in live animal evaluation.

REVIEW OF LITERATURE

Principles of Ultrasound

Properties. Sound is a mechanical wave of compressions and rarefactions within a medium. A sound wave can be compared to a longitudinal wave having a wavelength, frequency, and velocity. The wavelength is the distance of two similar points on a given wave. The frequency is the number of cycles or wavelengths occurring in a given time period (usually 1 second). Velocity is derived from the computation of frequency and wavelength. Frequency is described in terms of cycles per second or hertz (Hz). Audible sound varies from 20 to 20,000 Hz. Diagnostic ultrasound uses frequencies in the range of 2 to 10 megahertz (MHz), or 2 to 10 million cycles per second, which is well beyond the range of audible sound. If one knows the velocity and frequency, the wavelength can be calculated. Because the velocity of sound in a given tissue is constant, changing the frequency will change the wavelength. This will affect the resolution (Herring and Bjornton, 1985; Rantanen and Ewing, 1981).

Diagnostic ultrasound is produced by transducers housing crystals with piezoelectric (pressure-electric) properties. When piezoelectric crystals are deformed by pressure, electricity is produced. Conversely, when an electric current is applied to them, the crystals will

deform. This is the process by which ultrasound is generated and received by the transducer. Pulsed electrical deformation of the crystal produces small sound waves which impart kinetic energy to tissue molecules. There is a constant relationship between propagation velocity, wavelength, and frequency. When reflected sound returns to the transducer, a slight deformation of the crystal is produced which generates an electric current. This current is displayed on an oscilloscope as an image of the tissue interfaces (Rantanen and Ewing, 1981).

Interaction of sound waves with tissues. As the sound beam passes through body tissue, a portion of the beam is reflected back to the transducer. Reflection occurs at tissue interfaces of differing acoustic impedance. The amplitude of the returning echo is determined by the absolute difference in acoustic impedance of one tissue compared to another. The closer the acoustic impedance of one tissue is to a second tissue, the smaller the returning echo. The small echo will return to the transducer, where it is changed into an electrical pulse, and is displayed on a cathode ray tube screen. The ultrasound scanner calculates the time it takes for a pulse to be emitted and the echo to be returned, therefore allowing it to compute the exact distance of the acoustic interface from the transducer. Sound beam travels at approximately 1540 m per second in soft tissue. Therefore, the only variable that

contributes to the difference in acoustic impedance of one soft tissue to another is its density. When two tissues of different density are in contact with one another, this creates an acoustic interface or a reflecting surface. Sound travels through bone at approximately 3100 m per second. The density of bone is considerable when compared to soft tissue in which sound travels at 1540 m per second. Therefore, a very high impedance mismatch occurs at a soft tissue-to bone interface (Herring and Bjornton, 1985). The absolute value of the acoustic impedance of any tissue is relatively unimportant, but it is the magnitude of the difference in acoustic impedance at tissue interfaces that determines the amount of reflection of the beam (Rantanen and Ewing, 1981).

Energy is removed from the sound beam as is passes through soft tissues. This energy removal is referred to as attenuation. Attenuation is caused by two predominant processes. The first process is absorption which is the conversion of ordered motion of ultrasound into the disordered motion of heat. The amount of absorption increases with the frequency of the sound beam. The second process is scattering of the sound beam by small tissue interfaces which results in energy loss from the sound beam. The intensity of the scattered sound increases with its increasing frequency. Because the factors causing absorption and scattering of the beam are frequency

dependent, lower frequency will penetrate further into soft tissue than higher frequency sound (Rantanen and Ewing, 1981). For this reason, a 3 MHz transducer is more appropriate to use for deeper locations in the body (ie. muscle area) whereas a 5 MHz transducer is conducive for analyzing tissues close to the surface areas (ie. fat thickness).

Display formats. There are three basic display formats of modes. The first, called amplitude mode (A-mode) ultrasonic imaging is a one-dimensional display of returning echo amplitude and distance. This mode consists of vertical peaks along a horizontal axis. The height of the peak corresponds to the amplitude of the echo (Herring and Bjornton, 1985; Rantanen and Ewing, 1981).

Brightness mode (B-mode) ultrasonic imaging is another display format which is a two-dimensional display of dots. The transducer is moved across the surface of the body, and a cross sectional anatomy is depicted. The position of the dot on the screen is determined by the time it takes for an echo to return to the transducer. The brightness of the dots is proportional to the amplitude of the returning echoes. Real time ultrasonic imaging is a form of B-mode used to record movement of structures. In real time imaging, echoes are recorded continuously on a non-storage cathode ray display screen. This image may be frozen and photographed or recorded on videotape. The

transducer head of real time units is attached by a flexible cable. Encoders spatially orient the returning echoes on the display screen to depict tissue interfaces accurately. With real time units, these encoders are contained in the moveable head to allow rapid transducer movement from one area to another in contrast to the B-mode location in the scanning arms (Herring, 1981; Rantanen et al, 1985).

The third display format is that of motion mode ultrasound (time motion; M or TM-mode) and is a one-dimensional format displaying dots, as in B-mode, however the transducer is held in place over moving organs. The display is printed on an oscilloscope or moving strip of light sensitive paper. M-mode is used primarily in echocardiographic studies (Herring, 1981; Rantanen et al, 1985).

Statistical analysis. Confounding the acceptability or rejection of a method of assessment is the data interpretation which Cross (1982) has emphasized. Involved in the accreditation of instruments destined for measuring a particular trait is the statistical correlation coefficient. Too many times researchers misinterpret analysis due to over-dependency on this particular value. The correlation coefficient is influenced by the range of values in the sample on which it is based assuming both x and y are both random samples. The variation factor is an

item that should be of concern when comparing samples, not dependency on the final correlation coefficient.

Ultrasonic Investigations In Swine

Backfat. Initial investigations with the ultrasonic technique demonstrated the method to be relatively accurate for measuring fat thickness in swine (Dumont, 1957; Claus, 1957; Panier, 1957; Kliesch et al., 1957; Price, 1958; East et al., 1959; Hazel and Kline, 1959). The effect of different body positions on backfat thickness of hogs after slaughter was reported by Lauprecht et al. (1957). Backfat thickness was measured with an ultrasonic instrument at the shoulder, back, and longissimus muscle. After slaughter, one-half of each carcass was positioned to simulate the stance of the live animal by laying that half on a table. The remaining half-carcass was hung on a hook in the usual manner. Ultrasonic measurements were then made on the half-carcass sections in their respective positions. No significant differences were found between the ultrasonic live animal measurements and the measurements of the lying half carcass. Also, measurements with the ruler and ultrasonic technique in the hanging carcass were similar (Meyer et al., 1966).

Hazel and Kline (1959) reported on the accuracy of ultrasonic measurements in relation to fatness and percent lean cuts. Measurements of the fatness were made with

both the ruler probe and a Kelvin and Hughes Mark V flaw detector. The probing sites were about 2 inches off the midline of the back behind the shoulder, at the middle of the back and at the rear of the longissimus muscle (these were approximately located at the 6th rib, 12th rib, and last lumbar vertebrae, respectively). Ultrasonic measurements were made at frequencies of 1.5 megacycles/second (mc/s) and 2.5 mc/s. The correlations between average ultrasonic probe at a frequency of 2.5 mc/s and percent lean cuts was -.90. The corresponding correlations with probes at a frequency of 1.5 mc/s was -.76 while the mechanical probe was -.89.

Using a Branson Sonoray model 52 instrument but with a 2 mc transducer, Isler and Swiger (1968) studied the possibility of developing a simple equation for predicting lean cut percentage from regression analysis. Five ultrasonic measures of backfat depth (at the 4th, 8th and 12th ribs, 3rd lumbar and last lumbar vertebra) had correlations ranging from -.45 to -.63 with percent lean cuts. The two best sites being the 12th rib and 3rd lumbar. An ultrasonic ham fat measurement correlated -.54 with percent lean cuts. In addition, ultrasonic measurements of fat were more accurate in predicting lean cut percent than were carcass backfat measurements (average correlations of -.55 versus -.50). This difference was thought to be attributed to the fact that carcass fat was

measured on the midline while ultrasonic fat was measured over the longissimus muscle. Lean cut percent was predicted on the live animal utilizing six ultrasonic fat measurements and live weight with a correlation of .80. The addition of carcass longissimus muscle area to the prediction equation was of little value for increasing accuracy of estimating lean cut percent. The equation recommended from these researchers was as follows: Estimated % lean cuts = 65.4 + .066 live wt(kg) - .85 total ultrasonic backfat(cm) - 2.51 ultrasonic ham fat(cm).

Longissimus muscle area. In an initial attempt to measure longissimus muscle depth in swine, Price et al. (1960a) conducted an evaluation by ultrasonic reflection techniques. A Sperry Reflectoscope equipped with 2.25 mc crystal was utilized for the ultrasonic measurements coupled with angles of incidence at sites over the last rib. The means showed a tendency to overestimate the eye muscle size from an ultrasonically determined plot. This may have been due to the machine setting, differences in muscle size in the live animal as compared to the carcass, or a tendency to sketch the boundaries of the muscle area in a more rounding parameter than actually existed. Incomplete resolution to tissue layers introduced some subjectivity in longissimus muscle depth measurements. However, the actual and estimated mean muscle areas were not different. The correlation between ultrasonically

estimated longissimus muscle area and the actual area taken from tracings was .74.

Anderson and Wahlstrom (1969) utilized the Branson Model 12 machine equipped with a 2.25 mc transducer for the evaluation of the longissimus muscle area and the determination of the value of ultrasonic measurements taken at the 10th rib in predicting carcass composition. These authors found that the accuracy of estimating the area of the longissimus muscle was nearly the same when three or 10 ultrasonic measurements were used (r=.61 and .64, respectively). A prediction equation including age, one fat and one muscle determination accounted for 50% of the variation in predicting the longissimus muscle area.

In an effort to develop a faster and less expensive method of ultrasonically estimating longissimus muscle area in swine, Ramsey et al. (1972) attempted to form a prediction equation with a single ultrasonic depth measurement. Depth measurements, using a Sonoray instrument, near the center of the longissimus muscle produced the highest correlation (r=.91) with carcass longissimus muscle area at the 10th rib. Correlation coefficients with ham and longissimus muscle (r=.57) and lean cuts (r=.56) were comparable with the other depth locations. In agreement, Meyer et al. (1966) found great variation in muscle width which raised a serious question about the validity of assuming a standard muscle width for all

animals in a given weight range when using a single ultrasonic muscle depth measurement. Width of the longissimus muscle had a much lower correlation (r=.40) with longissimus area than did depth measurements. However, the relationships of the cut out measurements were similar for the width and depth measurements. Therefore, Ramsey et al. (1972) concluded that muscle width was of little practical importance in evaluating live pigs. In a second experimental report by these authors, correlations between ultrasonic depth measurements and actual area and depth of muscle in the carcass were .67 and .73. For estimating longissimus muscle area, this accuracy was comparable to that found by Price et al. (1960a; r=.74) and Stouffer et al. (1961; r=.70). Meyer et al. (1966) reported a range for correlation coefficients of .51 to .85 with an average correlation of .66.

Backfat and longissimus muscle area. Stouffer et al. (1961) developed an ultrasonic method of detecting borders of the rib-eye and associated fat in live animals with the ability to simultaneously record the results in a cross-sectional photograph with the intent of providing a more rapid animal evaluation. Using a Sperry Reflectoscope with a 1 mc transducer, readings were made at nine sites approximately over the 12th rib at one or one-half inch intervals off the midline at various angles of incidence. The reflected signal images resulting from individual

soundings were recorded with a 35 mm camera on the oscilloscope and later interpreted for depth measurements. The values were plotted and the area of estimated longissimus muscle and external fat thickness were measured from the plotted outline. Although this was a very time consuming process, the correlation coefficients between ultrasonic measurements in the live animal and carcass measurements produced significant results for fat thickness (r=.92) and longissimus muscle area (r=.72). Lower correlation coefficients were found with longissimus muscle depth (r=.47) and longissimus muscle length (r = .68). These investigators suggested that positional variation of the longissimus muscle and fat thickness between the 12th and 13th ribs could change the shape and size of the longissimus muscle due to slaughtering and hanging, and variability in transducer pressure against the hide during probing were factors accounting for differences in ultrasonic and carcass measurements.

Gillis et al. (1972) studied the relation of A-mode ultrasonics and ruler probe for the prediction of carcass yield and found that, on the average, the ultrasonic and ruler probe techniques appeared equal in accuracy for the measurement of backfat thickness in swine and that longissimus muscle area was measured with sufficient accuracy (coefficients ranging from .46 to .92) to be of value in selection programs.

Utilizing the Scanogram Model 722 ultrasonic machine, Mersmann (1982) found that ultrasonic backfat at 1/5 and 3/4 body length were less repeatable than those at 1/2 body length. This was attributed to the more complex muscle and adipose anatomy in the shoulder and loin regions than in the mid-back region so that any deviation from the exact location of an original scan by repeat scanning could result in variation in the resulting measurement. Ultrasonic backfat measurements were smaller than corresponding carcass measurements in the shoulder and midbody regions. Correlation coefficients ranged from .20 to .91, however, most were close to .70. In addition, shoulder and lumbar ultrasonic measurements taken off the midline were smaller in magnitude than those taken over the midline. Mean ultrasonic longissimus area was found to be similar to the mean carcass measurement. However, only modest correlations of about r=.49 were obtained when compared to the carcass. Mersmann (1982) noted that in his and previous studies, ultrasonic and carcass measurements may not be taken at the same anatomical locations. Ultrasound measurements are usually obtained on the live animal horizontally suspended in contrast to the classical measurements made on a carcass vertically suspended from the hind legs. Also noted was that other changes occur as the warm carcass rapidly undergoes complex shifts in muscle and fat areas as it hangs in a vertical position.

Much of the shift is toward the cephalad end because of the weight distribution. There are also shrinkage occurrences that contribute to differences between carcass and live animal measurements. Additionally, the live animal can move and preferentially contract muscles which may distort the ultrasonic images obtained. From this study, ultrasonic measurements were as well correlated as comparable carcass measurements with several indicators of body composition such as chemical composition variables and average backfat thicknesses.

In preliminary work utilizing the Technicare 210DX, Forrest et al. (1986) studied the accuracy of measuring body composition in the live animal and carcass. High correlations were obtained for ultrasonic tenth (r=.71) and last rib fat (r=.85) and last lumbar fat depth (r=.85) in comparison with tenth rib carcass fat depth. However, first rib fat depth correlations were much lower (r=.54). Tenth and last rib loin muscle areas were highly correlated with their respective carcass muscle areas (r=.65 and r=.68). Real-time ultrasonic measurements of longissimus muscle area and fat depth at the tenth rib on the warm carcass were nearly as good at predicting lean muscle mass as actual measurements made on the chilled carcass.

In an evaluation of the accuracy with which various methods can predict carcass composition, Doornenbal et al. (1962) utilized a Branson Sonoray instrument with a 1.6 mc

transducer to make an evaluation of a small group of animals. Actual chemical analysis of one side of the dressed carcass was the endpoint used for comparison. From the photographs of the plotted ultrasonic image, longissimus muscle area and fat area were measured with a planimeter. Ultrasonic fat was measured as the total area of an one inch long segment directly above the center of the longissimus muscle. From those measurements, the ratio of lean/fat in the 13th rib area was calculated. Other criteria evaluated were average backfat thickness of the first and last rib and last lumbar vertebra, carcass length and specific gravity. These researchers reported a low correlation of the ultrasonically determined lean/fat ratio in the 13th rib area with percent protein (r=.27) and percent fat (r=.28) and recommended further refinement of the ultrasonic technique before the method could be of any value in predicting carcass composition. Of the carcass measurements examined in their study, specific gravity showed the highest correlation with percent protein (r=.91) and percent fat (r=-.95) of the carcass.

Giles et al. (1981) compared techniques of three ultrasonic machines (Scanogram 721, Sonatest TE/6 and Scanoprobe) and the ruler probe as predictors of backfat thickness and longissimus muscle area. Operator experience effect was examined with the Sonatest and Scanoprobe with two forms of pig restraint (crate or nose rope)

compared using the Scanogram. Backfat measurements were taken while pigs were in a crate restraint which ventrally suspended the animal. The Sonatest proved to be more precise than the Scanoprobe (R^2=.81 vs. R^2=.56 to .64). A partial explanation for this may have been due to the Sonatest 5 MHz transducer compared to the Scanoprobe 2 MHz transducer. This was not indicated by these researchers, but, the 5 MHz would more clearly define the layers of tissue. The ruler probe was intermediate in precision (R^2=.74) and the Scanogram was the most precise (R^2=.89) of the techniques observed. Longissimus muscle area measurements using the Scanogram provided less precise results (R^2=.57) than had been previously found with backfat thickness measurements and no difference was obtained between the two types of restraint. Scanoprobe precision increased with operator experience but was still less accurate than the Sonatest where operator experience did not seem to affect precision.

In a comparison of three ultrasonic machines for predicting the body composition of live pigs, Alliston et al. (1982) used the Sonatest, Scanogram and Danscanner equipment. The Sonatest gave the most precise prediction with a single fat thickness measurement in comparison to the other two types of equipment. Precision was not improved by use of backfat area over the longissimus muscle or the longissimus muscle area itself. The area of

backfat over the longissimus muscle offered no advantage to individual measurements. Differences in precision between the instruments was small and no one instrument was consistently better than another over different measuring positions. This study, as with Kempster et al. (1979) indicated that the Scanogram and Danscanner offered no advantage over the simpler and cheaper Sonatest for predicting carcass lean content.

Hudson and Payne-Crostin (1984) tested four hand-held digital readout machines: the Medata Back Fat Grader; the Sonalyser Pig Monitor; the Illis Fat Test 747; and the Renco Lean-Meter. In addition, a fifth piece of equipment was used which was the Sonatest Model TE/69. Each piece of equipment evaluated the ability to predict carcass backfat thickness in pigs destined for slaughter. Realizing that location of measurement is a concern when comparing ultrasound measurements to the corresponding carcass measurements, these workers cited that Greer et al. (1983) found that to reduce inaccuracy in predicting last rib carcass backfat, the ultrasonic measurement on the live pig should be within an area 40 mm axially by 30 mm laterally and centered in the carcass site. Hudson and Payne-Crostin (1984) found their measurements to be well within those boundaries. The Sonatest gave the best prediction of carcass backfat thickness, being significantly better than the Illis and the Medata, but not

different from the Sonalyser and Renco. However, the difference between the coefficients of determination of each of the machines was not different. As with the majority of previous studies, the inclusion of live weight in the prediction equation improved prediction of carcass backfat thickness. The slight advantage in predicting last rib backfat provided by the Sonatest and Sonalyser was at the expense of increased difficulty in the use of those machines. The Illis, although among the easiest to use, performed the worst.

Wood (1986) reported results on four different machines: Illis TPM; Illis Fat Test; Ithaca Scanoprobe; and the Renco Lean-Meter. These were also compared to a metal probe measurement and the corresponding carcass measurements. All machines underestimated backfat thickness relative to carcass measurements and with considerable variability. This was especially evident in the shoulder and first rib region. The Illis TPM and Scanoprobe measured loin depth surprisingly well by being off by only .2 square inches or less, on the average. The highest correlations for backfat were between the live tenth rib estimate and carcass measurement. The Renco Lean-Meter was found to be most highly correlated with carcass measurements. Although few statistical differences were detected among machines or between people operating the same machine, in some cases, there were

differences between correlations obtained by different operators using one machine. Such differences indicate, that in some instances, training and skill is required in order to obtain consistent results.

Sather et al. (1986) studied the effect of operator, machine and site using the Krautkramer USM2, Scanoprobe 731A, and the Renco Lean-Meter. The machine by operator interaction indicated that the two operators interpreted the backfat measurements made by the three types of equipment differently. These authors pointed out that some operator bias must be tolerated, but, the bias could be minimized by use of technical standards training sessions. The Krautkramer and Scanoprobe produced similar results with a tendency for the Scanoprobe to measure a greater fat depth. The Lean-Meter gave fat depth greater than either of the other two equipment types. These researchers also stated that the differences among ultrasonic machines did not imply superiority or inferiority of one machine over the other, but they emphasized the need for a research program to use the same model to minimize machine bias. The larger differences between operators were associated with the sites with greater backfat depth, suggesting that better consistency between operators could be achieved when only the first two fat layers were measured.

Ultrasonic Investigations In Sheep

Backfat. Using three AIDD prototype pulse-echo instruments accompanied by a 5 MHz transducer, Gooden et al. (1980) set out to describe the relationships between ultrasonic fat depth measurements on the live animal and on the carcass, and between fat depths and carcass fat percent. Correlation coefficients of up to .91 were found between ultrasonic measurements over the longissimus muscle at the last rib and the corresponding carcass fat depths. Twelfth rib carcass fat depth measurement correlated with carcass fat percent resulted in a correlation coefficient of .80. The correlation coefficient for the relationship between ultrasonic backfat thickness measurements in vivo and carcass fat percent was .76, indicating that such measurements were of the same order of usefulness as the carcass measurements. These researchers indicated that the measurements may be useful as a potential aid in selecting sheep for breeding purposes.

Utilizing the Scanogram instrument to predict carcass chemical composition, Leymaster et al. (1985) chose four different sites for fat depth measurements: sternum, third coccygeal vertebra, scapula, and last rib. After removal of the variation due to live weight, ultrasonic measurements determined at the sternum and scapula did not account for significant variation in ether extract, protein, or ash. However, ultrasonic measurements at the

third coccygeal vertebra explained variation in ether extract, protein and ash. Significant effects of specific measurements at the last rib were detected for ether extract but not for protein or ash. Ultrasonic fat area measurements did not improve precision relative to linear measurements. Each linear measurement at the third coccygeal vertebra explained variation in ether extract, protein and ash whereas depth of fat at the last rib accounted for the variation in ether extract but not protein or ash. The most informative ultrasonic measurement for each compositional trait was fat depth at the fourth sacral vertebra (which was not a location previously investigated). The addition of a second ultrasound measurement to the prediction equation affected ether extract but had marginal effects on protein and ash.

Longissimus area. Attempts were made by Campbell et al. (1959) to estimate the size of the longissimus muscle in sheep with a somascope ultrasonic device. Three ultrasonic scanning sites located off the spinal column were chosen. The correlated loin muscle depth readings with the corresponding values for carcass tracing depth measurements resulted in correlations of .68 and .49 for two groups. Correlations of somascope measurements with longissimus muscle area provided values of .62 and .44.

Longissimus muscle area and total tracing depth were highly correlated with values of .76 and .79.

Backfat and longissimus area. Moody et al. (1965) investigated the usefulness of the ultrasonic technique to evaluate fat and longissimus muscle area using a Branson Model 5 ultrasound instrument equipped with a 2.25 mc transducer. Moody and colleagues found that, in general, the ultrasonically estimated longissimus muscle areas were underestimated by .17 square inches or less. The longissimus muscle area of 62% of the lambs was ultrasonically predicted within .1 square inches of actual area, 81% within .2 square inches, 94% within .3 square inches, 98% within .4 square inches and 99% within .5 square inches. Because of the comparatively small longissimus muscle area of lambs, a small difference between the actual and estimated area represents a substantial decrease in accuracy. Correlation coefficients between actual and ultrasonically estimated longissimus muscle area over a three year period were .52, .63, and .66 for each consecutive year. The higher relationship for succeeding years was attributed to more experience with the equipment and procedures. Selecting different locations for ultrasonic fat measurements over the 13th rib offered no advantage for predicting total trim carcass fat (nonsignificant correlations of .34, .27 and .31 reported for succeeding years). Width and depth of longissimus muscle were corre-

lated with ultrasonically estimated area and actual carcass area tracings of the longissimus muscle. The correlations between width and area (r=.66, actual and r=.36, ultrasonic) were higher than between depth and area measurements (r=.56, actual and r=.31, ultrasonic). Actual width and depth measurements, when correlated with longissimus muscle area, were different from ultrasonic measurements. These researchers pointed out that the depth measurement was of practical importance since it could be estimated ultrasonically on the live lamb, whereas the width of the longissimus muscle was difficult to obtain. Correlations between actual longissimus muscle area and weight of separated muscles from the leg and loin were slightly higher than the same variables with ultrasonically estimated longissimus muscle area. Therefore it was concluded that ultrasonically estimated longissimus muscle area was considered useful and of practical importance.

In a preliminary evaluation of the Scanogram ultrasound equipment for predicting the carcass composition of live lambs, Kempster et al. (1977) took cross-sectional scans of the longissimus muscle and the overlying fat at the 12th rib. These researchers found that the addition of fat area over the longissimus muscle to live weight in multiple regression analysis significantly improved the precision. However, the addition of longissimus muscle

area as a further independent variate in the regression model produced only a small improvement in precision. The results suggested that the Scanogram could be used in experimental work where it was necessary to select lambs for slaughter at a constant fatness, but it was questionable whether the level of precision was sufficient for use in performance testing.

Work conducted by Thompson and colleagues (1977) also utilizing the Scanogram equipment provided results which indicated that the ultrasound device was limited to differentiating between individual animals of widely differing carcass composition. The repeatability of scan interpretations of fat depth and longissimus muscle area was of the order of .75 with the exception of shoulder fat depth which was .48. Simple correlation coefficients between scan and carcass measurements were significant for 12th rib and tuber coxae fat depth ($r=.74$ and $r=.64$, respectively) but not for shoulder fat depth and longissimus muscle area. Scanogram measurements of fat depth at the 12th rib and tuber coxae sites were the best predictors of percentage fat, and when considered in combination with live weight provided the best estimate of total carcass fat. Live weight was the best predictor of total muscle weight and the addition of Scanogram measurements to live weight did not improve the accuracy of prediction.

Fortin (1980) compared three ultrasonic instruments as estimators of fat thickness for cutability prediction. The instruments were the Krautkramer USM #2, Scanoprobe Model 731A and the Scanogram Model 722. Results from Fortin's research pointed out that the mean estimated backfat thickness for the Krautkramer and the Scanoprobe were larger than the Scanogram and carcass ruler measurements. This was attributed to the skin thickness inclusion in the fat measurement with the former instruments. Weight of trimmed or boneless cuts was predicted with more precision than percentage of trimmed or boneless cuts. Fat thickness measurements from the three ultrasonic instruments alone or combined with weight at scanning was of no significant value in the prediction of percentage of trimmed cuts. Percentage of boneless cuts was predicted more efficiently from weight at scanning alone than from fat thickness alone or combined with weight at scanning. Fat thickness measured with the Krautkramer was more efficient in its prediction of cutability than fat thickness measured with the Scanoprobe or Scanogram. However, it was concluded that over the range of live weights studied , the usefulness of fat thickness measured on live lambs to predict cutability was questionable.

Kempster et al. (1982) conducted a study to provide more information on the precision of the Scanogram for use with sheep and to compare their results with those of the

more complex scanner, the Danscanner. Scan measurements taken at the cross section of the longissimus muscle at the 12th rib for fat thickness and fat area over the longissimus muscle with the Scanogram were lower than the corresponding carcass measurements. Whereas, fat measurements taken by the Danscanner were higher but those measurements included skin thickness. There was good agreement between longissimus muscle area measurements using the different techniques. The ultrasonic measurements provided a significant improvement in precision when added to live weight at evaluation in a multiple regression equation and the Scanogram was slightly better generally than the Danscanner in predicting carcass measurements. At best, the scanning machines only accounted for 25% of the variation in longissimus muscle area. For the prediction of carcass lean content, the Scanogram provided only slightly better results than those for the Danscanner. Fat areas did not offer a consistent advantage over fat depth for the Scanogram, although they did for the Danscanner. The addition of longissimus muscle area to live weight at evaluation and fat areas did not improve the precision of prediction of tissue proportions. Consistent with reports of other studies, the researchers indicated that scan measurements of fat area may be used to predict carcass composition of lambs of the same breed, sex, and live weight, but with low precision.

The authors concluded that it was debatable whether the predictions were precise enough for practical application. The suggestion was made to anyone considering the use of ultrasonic evaluation to build into their work a trial involving carcass evaluation. This would help establish what the prediction relationships are under the circumstances in which the machine is to be used.

The Scanogram and Krautkramer ultrasonic instruments were used in a study conducted by Fortin and Shrestha (1986) to evaluate the usefulness of ultrasonic backfat thickness and longissimus muscle measurements to predict carcass composition in lambs varying widely in their genetic makeup and scanned over a large range of weights. There was close agreement between fat thickness measured with the Scanogram and the carcass. No clear trends were detected between the ultrasonic and carcass muscle measurements. Low correlations between ultrasonic measurements and corresponding carcass measurements further illustrated the poor agreement between measurements. The precision with which the ultrasonic measurements combined with live weight at scanning predicts trimmed boneless meat is a modest improvement in precision achieved by using only live weight.

With the knowledge of previously reported negative results from other researchers, Clements et al. (1981) proceeded with an ultrasonic scanning trial to compare the

Scanogram and Scanoprobe instruments and condition scoring techniques as a predictor of carcass fat depth. The Scanogram was the most accurate predictor of fat depth at the 12th/13th rib and soft tissue depth, although confidence intervals calculated from the residual standard deviations were relatively large. In agreement with Kempster et al. (1977) and Thompson et al. (1977), this study indicated that use of the Scanogram was restricted to discriminating between individuals of widely differing fatness. Its accuracy was improved by the addition of live weight values. Therefore, unless a live weight correction was made, comparison of Scanogram measurements would need to be limited to animals within a restricted weight range. Also, the higher costs associated with the instrument would confine its use to breeding programs or experiments. Condition scores were the next best predictors of the same measurements in the carcass and the accuracy of condition scores by the best operator was largely independent of variation in live weight. The Scanoprobe was the poorest predictor of fat depth and soft tissue depth measurements in the carcass, which suggested that even when a relatively low degree of accuracy was acceptable, the Scanoprobe would still be of little value. Clements and colleagues pointed out that the small size of fat depth in sheep compared with other species (particul-

arly pigs) appeared to be beyond the resolution power of the Scanoprobe.

To compare three ultrasonic machines - Danscan, AIDD, and Body Composition Meter - and subjective fat and conformation scores for predicting chemical composition of live sheep, Bass et al. (1982) conducted two trials. The second trial was an extension of the first in that by trial two the inexperienced operator of the Body Composition Meter in trial one was now familiar with the operation of the instrument. In trial one, the AIDD ultrasonic machine was consistently better than the other ultrasonic machines at predicting chemical composition of the carcass. However, in trial two, the Body Composition Meter achieved results similar to the AIDD instrument. Not only did the Danscan account for a smaller proportion of the variation of carcass chemical composition than the AIDD instrument, but, because of its large scanning head, also required careful shearing to achieve good acoustic contact which diminished the commercial usefulness of the Danscan. As with Clements et al. (1981) some judges' fat scores and condition scores were highly related to carcass fatness after adjustment for live weight. However, conformation scores failed to improve the prediction of chemical composition when the effect of live weight and fat score had been removed. The top judges were as good at predicting carcass composition as the AIDD ultrasonic

fat depth measurements, which was the best of the ultrasonic machines.

Purchas et al. (1981) studied the repeatability of ultrasonic fat depth measurements made on sheep from seven to 18 months of age to ascertain whether such measurements made at one age were likely to provide useful information on differences in fatness at a later age. The instrument used in this study was an AIDD pulse-echo machine, similar to that used by Gooden et al. (1980). Repeatability of the fat depth deviations ranged from .56 to .72 for the groups of sheep. Weight corrected measures of fat depth in terms of percentage deviation values were moderately repeatable, so the sheep that were fat for their weight at seven to eight months of age were likely to retain that characteristic up to at least 15 to 18 months of age. The corresponding linear measures for body length deviations and withers height deviations were less repeatable.

Summary

Previous research provides an indication of the potential usefulness of ultrasonics to the livestock industry. Although beef research in this area was not reported herein, its importance and contributions should not be overlooked. There are concerns associated with any type of technology and methodology. Studies conducted on

ultrasonic technique have revealed considerable technology progression and progress in its application to the livestock industry.

Ultrasonics has been employed to measure depths of fat and muscle area in numerous sheep and swine reports. Several anatomical sites for fat and muscle measurements have been investigated. Generally, those that provided the best indicators for each of those criteria have been in the thoracic and lumbar areas of the body. The objectiveness of ultrasonics is still dependent on the equipment operator's experience with position and movement of the animal influencing the measurements being estimated. There is also speculation that live animal ultrasonic measurements, when related back to the carcass, could be influenced by carcass chilling and shifting of tissues during that process. Relationships between fat thickness or longissimus muscle area measured ultrasonically in the live animal and carcass composition have been similar to relationships between the same measurements of the carcass and carcass composition. Factors are involved which necessitate further research to help explain remaining questions and hypotheses. The livestock industry needs a method of live animal evaluation for selection, marketing and research purposes with the ultrasonic technique having the capabilities of replacing subjective methods of evaluation.

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COMPARISON OF ULTRASONIC MEASUREMENTS IN SWINE WITH CORRESPONDING MEASUREMENTS IN HANGING AND STANDING CHILLED SIDES

Introduction

The concept of ultrasonic estimation of composition in live meat animals is not new (Stouffer, 1969). Numerous researchers have reported that ultrasonics are an objective method of estimating subcutaneous fat thickness (Dumont, 1957; Claus, 1957; Panier, 1957; Kliesch et al., 1957; Hazel and Kline, 1957; Price et al., 1960; Meyer et al., 1966; Isler and Swiger, 1968; Stouffer et al., 1961; Gillis et al., 1972; Mersmann, 1982; Hudson and Payne-Crostin, 1984; Forrest et al., 1989; Sather et al., 1986; Wood, 1986; Busk, 1986) and longissimus muscle area ((Price et al., 1960a; Anderson and Wahlstrom, 1969; Ramsey et al., 1972; Meyer et al., 1966; Stouffer et al., 1961; Gillis et al., 1972; Alliston et al., 1982; Mersmann, 1982; Forrest et al., 1989; Busk, 1986; Wood, 1986). In contrast, several investigators have found discrepancies in using ultrasound to measure carcass characteristics in live swine (Doornenbal et al., 1962; Hudson and Payne-Crostin, 1984; Alliston et al., 1982; Kempster et al., 1977; Giles et al., 1981; Sather et al., 1986). A potential reason for variation in the data is due to the instrumentation used (Turlington et al, 1986). Other differences between

ultrasonic and actual carcass measurements may be due to shifts in tissues during the chilling process (Stouffer, 1961; Mersmann, 1982). Lauprecht et al. (1957) investigated the effects of carcass chilling position on subcutaneous fat thickness but found few differences.

Our objectives in this study were 1) to determine the accuracy of ultrasound measurements in live animals as cold carcass measurements, 2) to evaluate the effects of cold carcass position (hanging vs standing) on various carcass measurements, and 3) to compare ultrasound live animal measurements and chilling positions in predicting lean carcass content.

Experimental Procedures

Source of Data. Data were collected on three groups of 25 castrated male crossbred swine (Duroc x Hampshire x Spotted Poland China x Pietrain). Market weight pigs were randomly selected from the swine herd at the Roman L. Hruska U. S. Meat Animal Research Center located near Clay Center, Nebraska. Individual weights were obtained 24 h prior to slaughter.

Ultrasonic Methodology. Each animal was ventrally suspended in a special tubular steel crate and ultrasonically scanned with a Technicare 210DX (Corometrics Medical Systems, Inc., Wallingford, CT) 1 d before slaughter. A 3 mHz transducer was used. Mineral oil was

applied at the location sites to ensure adequate acoustic contact. The ultrasonic equipment was subjectively adjusted at each scanning site to provide interpretable images. Four different sites were chosen for scanning: 1) the first rib, 2) the tenth rib, 3) the last rib and 4) the last lumbar vertebra. Backfat was measured at each site and longissimus muscle area, depth and width were measured at the tenth rib. Preliminary work indicated the first rib (BF1) to be located in front of the shoulder. Assuming swine have, on the average, fifteen ribs, the tenth rib (BF10) location was achieved by counting five ribs forward of the last rib (Kempster et al., 1982). This was aided by use of the 3 mHz transducer image of the ribs. The last rib (BF2)was located by palpation of the site and last lumbar vertebra (BF3) was estimated at the loin-ham juncture. The average of BF1, BF2, and BF3 was computed and reported as the average backfat (BFAV). All sites were denoted by scalpel mark on the live animal so that post-slaughter measurements and location sites could be evaluated. Ultrasonic measurements were made on alternate right and left sides of animals perpendicular to the cephalic-caudal axis. Alternate sides were scanned to alleviate any possible bias that could be influenced due to differences in sides.

Subcutaneous backfat readings were made directly from the ultrasonic image by caliper mark movement. The

distance between the two caliper marks was presented in a centimeter (cm) readout on the ultrasound equipment screen. A portable video tape recorder interfaced with the Technicare unit and a 3.05 cm diagonal television allowed longissimus muscle area (LMA) tracings to be made at time of scanning. A scaling factor to reduce longissimus muscle area tracings by twenty percent was used for final area determination.

One technician was responsible for interpretation of ultrasonic images and determination of linear and area measurements to avoid variation (Turlington et al., 1987). All measurements excluded skin thickness. Thickness of subcutaneous fat 2 cm lateral to the dorsal mid-line at the first rib was measured. The ultrasonic scan at the tenth rib provided an estimate of fat depth three-fourths the lateral length above the LMA and also enabled a tracing to be made of the longissimus muscle area. Estimates were made of fat depth 2 cm lateral to the dorsal mid-line of the last rib and last lumbar vertebra.

Chilling Methodology. Stands were constructed so that half of each carcass was positioned to simulate the stance of the live animal. The side of the live animal scanned was also the side which was positioned on the stand. The construction of each stand was such that a portion of the carcass vertebral process fit over the lip on the top edge of the stand. Two stainless steel rods

were inserted through the carcass half (with minimal distortion of tissues) to aid in holding the carcass section in a standing position. The remaining half-carcass was hung in the traditional manner.

Carcass measurements were obtained on half-carcass sides after at 5 C for 24 h. These measurements included carcass backfat (first rib, last rib and last lumbar vertebra), carcass longissimus muscle area depth (LMD) and width (LMW) above the longissimus muscle at the denoted 10th-11th rib interface and carcass backfat at 3/4 the lateral length of the longissimus muscle at the 10th-11th rib. All carcass measurements were made at the site in which the live ultrasonic measurements had been made. However, denoted measurement locations and their distances from the actual intended measurement locations were location. Ultrasonic and carcass longissimus areas were determined using a digital planimeter on tracings.

Lean content of experimental animals was estimated using an equation determined by Grisdale et al. (1984) based on hot carcass weight, longissimus area and tenth rib backfat regardless of weight or age. Assuming a dressing percent 73% carcass dressing rate, hot carcass weight (HCWT) was estimated from live weight. Estimated HCWT and carcass measurements from the live animal, hanging cold carcass and standing cold carcass were used to predict lean content for the different positions

studied. Lean content was determined using actual carcass data (hanging and standing) as well as ultrasonic estimates.

Statistical analysis. Data were analyzed using SAS (1982), testing for interactions between groups of animals and criteria measured. Simple correlations, cumulative frequency comparisions and least significant differences (LSD) were determined for data collected at the different carcass positions (live animal, hanging cold carcass, and standing cold carcass). Stepwise regression procedures were used to compare lean content for the different positions studied.

Results and Discussion

No group by carcass position interactions were present, thus, data were pooled across the three groups.

Ultrasonic and carcass measurements often are not taken at the same anatomical location (Mersmann, 1982). For this reason, in the current study, scanning sites were denoted on the live animal and followed through to the carcass. Instead of ruler measurement, this was observed by the number of ribs front or back of the actual location. Upon follow-up on the chilled carcass, the average divergence from any measurement site was 1/2 rib forward or backward. Anatomical location was not a factor of concern in the current study.

Means and differences for live animal ultrasound (LU) measurements, hanging (HCC) and standing (SCC) cold carcass side measurements are shown in table 1. Live ultrasonic measurements of backfat and longissimus muscle area were smaller than the hanging carcass measurements. Live animal ultrasonic measurements and standing carcass measurements were numerically similar with the exception of LMA. Backfat measurements of HCC were greater in magnitude for BF1, BF2, BF3 and BFAV than those of the LU and SCC ($P<.01$). The greatest difference was observed at the BF1 location (4.26 cm (HCC) vs 3.91 cm (LU) and 3.94 cm (SCC)). Sather et al. (1988) reported that measurements taken on the live pig will be lower than corresponding measurements taken on the hot hanging carcass. Likewise, measurements taken 24 h post-slaughter on the cold carcass would be even smaller than hanging carcass measurement. Previous investigators supported the tendency for ultrasonic machines to underestimate backfat, relative to the carcass measurements (Wood, 1986; Mersmann, 1982). Sather et al. (1982) supported these findings by reporting that during slaughter, dressing, and hanging of the carcass, compression of the fat layers occurred along the longitudinal axis and increased the apparent fat thickness. The results of the present study seem to agree with these investigators in regard to the relationship of live ultrasonic backfat measurements to the hanging carcass.

This does not explain, however, the observations for the standing carcass backfat measurements. Most likely, the positional difference of the carcass (standing vs hanging) affects the fat layers in a slightly different magnitude from that reported by Sather et al. (1982).

Price et al. (1960) and Busk (1986) reported longissimus muscle area wa slightly overestimated from an ultrasonically determined plot. The instrumentation evaluated in their studies was different from the present study. This was not the case for the current data with respect to the chilled hanging carcass side or the standing carcass side. Longissimus muscle area of the HCC was greater ($P<.001$) than either the LU position or the SCC position (table 1). However, LU loin area measurements were greater ($P<.02$) than the SCC measurements taken at the same tenth rib location. The discrepancy is difficult to explain, however, equipment differences and interpretation of images may have been part of the reason for what was observed in the present study. Hanging cold carcass BF10 measurements were greater ($P<.001$) than those measurements taken on the SCC ($P<.001$) and the live animal ($P<.02$).

To aid in understanding differences observed between HCC and SCC longissimus muscle area measurements after chilling, depth (LMD) and width (LMW) of the area was measured. Measurements on the HCC indicated that there

was greater muscle depth through the center of the longissimus muscle than observed in the SCC ($P<.001$). Measurements of LMW indicated that the SCC areas were wider than the respective measurements observed in the HCC ($P<.001$).

Simple correlation coefficients of HCC measurements and SCC measurements with LU measurements are shown in table 2. Live animal ultrasound backfat measurements at the first (BF1) and last rib (BF2), last lumbar (BF3), tenth rib (BF10), and the average of the first three (BFAV) were correlated positively to all positional cold carcass backfat measurements. Live animal ultrasound backfat measurements were correlated similarly to those of the hanging and standing carcass with the exception of first rib. First rib ultrasound measurements were more poorly correlated ($r=.74$) with the hanging carcass than the standing carcass ($r=.90$). A possible explanation for the poorer correlation of LU BF1 measurement with HCC BF1 is the influence of carcass weight and chilling position upon the HCC BF1 measurement. The best correlation for fat thickness between the live estimate and carcass was achieved at the tenth rib for the hanging carcass. This has also been reported by Busk (1988) and Wood (1986). Ultrasonically measured tenth rib loin muscle area was correlated highly with tenth rib area of the hanging and standing carcass ($r=.91$ and $.93$) and negatively related to

all backfat measurements. Previous investigations revealed somewhat poorer correlations than reported in the present study between live animal ultrasonic backfat and longissimus area measurements (Forrest et al., 1989; Wood, 1986). Width of the longissimus muscle had a much lower correlation with longissimus muscle area (HLMW = .57; SLMW = .63) than the depth measurements (HLMD = .84; SLMD = .84). In agreement, Ramsey et al. (1972) found that the relationships of longissimus muscle depth and width to the actual chilled carcass side LMA measurements were similar. Meyer et al. (1966)found great variation in longissimus muscle width which raised a serious question about the validity of assuming a standard muscle width when using a single ultrasonic muscle depth measurement.

Simple correlation coefficients between HCC side measurements and SCC side measurements are presented in table 3. Among the carcass measurements taken on the chilled sides (HCC and SCC), tenth rib backfat and longissimus muscle area had the highest correlation coefficients (r=.93) compared to the other measurements. However, correlation coefficients of .60 to .81 were obtained for the remaining trait comparisons. This included comparisons of longissimus muscle depth and longissimus muscle width between the carcass positions.

Simple correlations may be misleading due to characteristics of the population evaluated (Cross, 1982).

Therefore, cumulative frequency (%) comparisons of live animal ultrasound measurements in estimating hanging and standing carcass measurements are reported to show how accurate ultrasound can estimate the actual carcass measurements. (table 4). Cumulative frequency comparisons further support the accuracy of measuring carcass traits in the live animal with ultrasound. With all measurements, live animal ultrasound predicted standing carcass measurements with less divergence than the hanging carcass measurements. Although ultrasonic measurements were more closely related to the SCC, hanging carcasses are representative of present chilled carcass positions in the packing plant. This data indicates that ultrasonically determined carcass measurements can account for HCC side measurements with a high degree of accuracy. For example, longissimus muscle area and backfat at the tenth rib were determined within 2.58 cm^2 and .508 cm, respectively, 85 to 90% of the time using ultrasound on live animals. This would estimate LMA and BF10 for the hanging carcass within 2.8% and 16.6%, respectively.

Determining lean composition of market weight pigs is often needed yet is time consuming, expensive and inconvenient. Using the estimated HCWT and carcass measurements obtained from the live animal, hanging cold carcass and standing cold carcass, the lean content of the experimental animals was estimated to be 39.1, 39.0 and

39.2 kg, respectively. Each of the estimated lean contents were highly correlated to one another (r = .999). Since hanging carcass measurements are more indicative of current practices, lean content estimated from hanging carcass measurements are more readily accepted by the industry. Regression analysis of ultrasonic estimation of lean content onto lean content estimate using hanging carcass data revealed the following relationship:

Actual lean, kg =-2.79+1.05(ultrasonic lean, kg); R^2 = .88.

Thus, ultrasonically determined carcass measurements in live swine offer a viable alternative to estimating lean content regardless of the differences observed in cold carcass positions.

Lauprecht et al. (1957) concluded that no differences were found between ultrasonic live animal backfat thickness measurements of half carcasses laying on a table to simulate the stance of the live animal. The results of the present study are in disagreement with Lauprecht et al. (1957). Live animal ultrasound fat thickness measurements were more closely associated to standing cold carcass fat measurements than to hanging cold carcass measurements. Moreover, hanging cold carcass fat thickness measurements were greater than either live ultrasound or standing carcass fat thickness measurements. Similarly,

hanging cold carcass longissimus muscle area was greater than either live animal ultrasound or standing carcass measurements. Although live animal ultrasound longissimus area was greater than the actual standing carcass longissimus muscle area, numerically, live animal ultrasound was more similar to the standing cold carcass measurement. Thus, live animal estimations of carcass measurements by ultrasound were more closely related to carcass measurements from a standing rather than a hanging position. This is further supported by the cumulative frequency comparisons of ultrasonic live animal measurements to the hanging and standing cold carcass measurements. However, obtaining standing cold carcass data is impractical under typical industry conditions. Ultrasonic evaluation of live swine is a reliable method of estimating actual carcass measurements. However, ultrasonic measurements are more closely associated with carcass measurements taken on a standing cold carcass.

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TABLE 1. DIFFERENCES AMONG LIVE ANIMAL ULTRASOUND MEASUREMENTS, HANGING COLD CARCASS SIDE MEASUREMENTS AND STANDING COLD CARCASS SIDE MEASUREMENTS.

Measurements	Live Animal	Hanging Carcass	Standing Carcass	S.D.
Weight, kg				
- live	102.61	-	-	5.49
- cold carcass	-	37.55	37.73	2.19
Backfat, cm				
- first rib (BF1)[a]	3.91	4.26	3.94	.12
- last rib (BF2)[a]	2.62	2.79	2.63	.08
- last lumbar(BF3)[bc]	2.82	2.97	2.71	.15
- average (BFAV)[a]	3.12	3.34	3.09	.08
- tenth rib(BF10)[cd]	2.99	3.07	2.92	.09
Longissimus muscle, tenth rib				
- area, cm^2(LMA)[ae]	34.62	35.76	34.00	.23
- depth, cm (LMD)[f]	-	5.38	4.72	.11
- width, cm (LMW)[f]	-	8.56	9.10	.16

[a]Hanging carcass vs live animal and standing carcass (P<.001).
[b]Live animal vs hanging carcass (P<.01).
[c]Hanging carcass vs standing carcass (P<.001).
[d]Live animal vs hanging carcass (P<.02).
[e]Live animal vs standing carcass (P<.01).
[f]Hanging vs standing carcass (P<.001).

TABLE 2. SIMPLE CORRELATION COEFFICIENTS FOR LIVE ANIMAL ULTRASOUND MEASUREMENTS VERSUS HANGING AND STANDING COLD CARCASS MEASUREMENTS[a]

	Live Animal Ultrasound Measurements					
Measurements	BF1	BF2	BF3	AVGBF	BF10	LMA
Hanging Carcass						
HBF1	.74	.44	.46	.67	.52	-.11
HBF2	.41	.83	.68	.75	.64	-.22
HBF3	.44	.64	.90	.80	.72	-.52
HBFAV	.66	.75	.84	.91	.77	-.37
HBF10	.52	.74	.82	.83	.93	-.60
HLMA	-.22	-.36	-.58	-.47	-.56	.91
HLMD	-.22	-.37	-.58	-.48	-.55	.84
HLMW	-.11	-.24	-.41	-.31	-.41	.57
Standing Carcass						
SBF1	.90	.29	.43	.68	.46	-.27
SBF2	.31	.83	.66	.70	.61	-.25
SBF3	.37	.58	.90	.70	.66	-.48
SBFAV	.65	.69	.80	.87	.73	-.45
SBF10	.51	.73	.78	.80	.88	-.52
SLMA	-.31	-.34	-.59	-.51	-.61	.93
SLMD	-.38	-.43	-.61	-.58	-.61	.84
SLMW	-.08	-.20	-.30	-.23	-.40	.63

[a]Correlation >.22 (P<.05); correlation >.29 (P<.01); correlation >.43 (P<.001).

TABLE 3. SIMPLE CORRELATION COEFFICIENTS FOR HANGING COLD CARCASS SIDE MEASUREMENTS VERSUS STANDING COLD CARCASS SIDE MEASUREMENTS[a]

	Hanging Carcass Measurements							
Criteria	HBF1	HBF2	HBF3	HBFAV	HBF10	HLMA	HLMD	HLMW
Standing Carcass								
SBF1	.60	.37	.42	.58	.48	-.23	-.21	-.15
SBF2	.36	.70	.60	.66	.63	-.31	-.35	-.20
SBF3	.40	.50	.73	.68	.66	-.49	-.47	-.38
SBFAV	.56	.63	.75	.80	.75	-.46	-.45	-.33
SBF10	.49	.67	.72	.76	.93	-.56	-.58	-.38
SLMA	-.21	-.27	-.57	-.45	-.65	.93	.83	.60
SLMD	-.29	-.38	-.58	-.52	-.67	.83	.81	.45
SLMW	-.09	-.08	-.27	-.19	-.37	.64	.47	.72

[a]Correlation >.36 (P<.001); correlation >.27 (P<.01); correlation >.08 (P<.50).

TABLE 4. CUMULATIVE FREQUENCY COMPARISON OF LIVE ANIMAL MEASUREMENTS IN ESTIMATING HANGING AND STANDING COLD CARCASS MEASUREMENTS

	Unit Differences							
cm	±.127	±.254	±.381	±.508	±.635	±.762	±.889	±1.02
cm^2	±.322	±.645	±.968	±1.29	±1.61	±1.94	±2.26	±2.58
	Cumulative Frequency, %							
Hanging Carcass								
BF1, cm	50.1	62.7	73.3	78.7	80.0	86.7	93.3	96.0
BF2, cm	53.3	73.3	88.0	92.0	97.3	98.7	98.7	98.7
BF3, cm	70.7	88.0	93.3	93.3	93.3	94.7	96.0	98.7
BFAV, cm	45.3	69.3	81.3	89.3	92.0	98.7	98.7	98.7
BF10, cm	58.7	74.7	82.7	89.3	93.3	94.7	96.0	97.3
LMA, cm^2	37.3	42.7	52.0	58.7	69.3	76.0	80.0	85.3
Standing Carcass								
BF1, cm	82.7	93.3	96.0	97.3	97.3	100.0	-	-
BF2, cm	80.0	89.3	97.3	98.7	100.0	-	-	-
BF3, cm	94.7	97.3	97.3	97.3	97.3	97.3	98.7	98.7
BFAV, cm	86.7	96.0	98.7	98.7	98.7	98.7	98.7	98.7
BF10, cm	78.7	88.0	92.0	93.3	96.0	97.3	98.7	100.0
LMA, cm^2	88.0	97.3	98.7	98.7	100.0	-	-	-

EVALUATION OF REAL-TIME ULTRASOUND TO PREDICT SHEEP CARCASS COMPOSITION AND MEASUREMENTS

Introduction

One of the major deterrents to improving carcass composition in sheep is a lack of accurate methods for obtaining carcass measurements in live animals. Complete physical dissection of the entire carcass has provided the most accurate determination of carcass composition, however, this is costly and not very practical.

Using sheep, Gooden et al. (1980) reported correlation coefficients of up to .91 between ultrasonic measurements over the longissimus muscle at the last rib and the respective carcass measurements. In contrast, Leymaster et al. (1985) reported ultrasonic carcass measurements were not good predictors of carcass chemical composition. Attempts have been made to estimate carcass measurements and lean composition of sheep with a variety of success using a Scanoscope (Campbell et al., 1959; Clements et al., 1981), a Branson Model 5, "A" Scan (Moody et al., 1965), a Scanogram (Kempster et al., 1977; Thompson et al., 1977; Fortin, 1980; Clements et al., 1981; Kempster et al., 1982b), a Danscanner (Bass et al., 1982; Kempster et al., 1982b), or an AIDD (Purchas et al., 1981; Bass et al., 1982).

The objective of this study was to evaluate real-time model ultrasound of estimating carcass composition and carcass measurements in sheep.

Experimental Procedures

Source of data. An experimental group of 162 ram lambs were part of a comprehensive study to evaluate *in vivo* techniques to estimate carcass composition at the Roman L. Hruska U. S. Meat and Animal Research Center located near Clay Center, Nebraska. As a second objective, real-time ultrasound was evaluated as a predictor of carcass measurements. Lambs were produced from a composite population (50% Columbia - 25% Suffolk - 25% Hampshire).

Ultrasonic methodology. The experimental animals were equally divided among four contemporary groups representing similar birth dates. At 17 weeks of age, lambs were ultrasonically scanned with a Technicare 210DX (Corometrics Medical Systems, Inc., Wallingford, CT) ultrasound machine. Wool was shorn from the scanning sites and mineral oil was applied to ensure adequate acoustic contact. The ultrasonic equipment was subjectively adjusted, as necessary, to provide interpretable images. Two sites were chosen for scanning: 1) between the 12th and 13th ribs (last rib) and 2) at the fourth sacral vertebra (dock). Measurements taken at the last rib location were fat depth on the midline, fat depth above

the longissimus muscle at 3/4 of the lateral distance over the longissimus muscle (3/4 location) and longissimus muscle area (LMA). At the dock location, fat depth on the midline was measured. A 5 mHz transducer was used to estimate the fat thickness at both midline sites. A 3 mHz transducer was utilized for estimating last rib fat depth (3/4 location) and LMA. Two transducers varying in frequency were used due to the greater sensitivity of the 5 mHz in measuring fat thickness. This was especially important due to the minimal fat cover that the lambs possessed. The 3 mHz transducer has a greater capability of encompassing the loin muscle and penetrating further into the soft tissue (Rantanen and Ewing, 1981). Thus, LMA can be measured more readily with the 3 mHz transducer than with the 5 mHz transducer. Scanning sites were located by palpation of the last two ribs and the base of the dock. All ultrasonic measurements were made on the left side of the lambs perpendicular to the cephalic-caudal axis. Scanning locations were not denoted on the live animal for follow-up carcass examination. It was assumed that these locations would be found on the carcass with minimal error.

Subcutaneous backfat readings were made directly from the ultrasonic image by movement of caliper marks. The distance between the two caliper marks was measured in centimeters (cm). A portable video tape recorder interfaced with the Technicare 210DX unit and a 30.5 cm diagonal

television allowed LMA images to be traced for later interpretation. A scaling factor to reduce LMA tracings by twenty percent was used for final muscle area determination.

Chilling methodology. Lambs were slaughtered on an average of two days following ultrasonic scanning. Chilled carcass weights and carcass measurements were taken on the left carcass side 24 h following slaughter at the same locations reported earlier. All carcass measurements, with the exception of fat depth at the dock, were taken after the carcasses were split along the median plane. One side of each carcass, including kidney fat and skeletal tissue, was ground three times for chemical compositional analysis by researchers at the Roman L. Hruska U. S. Meat and Animal Research Center (MARC). For each animal, three samples of ground tissue, approximately 100 g each, were taken for determination of water content, chemical fat (ether extract), protein (N x 6.25) and ash. Carcass fat-free soft tissue mass was defined as the sum of carcass water and chemical protein (Jenkins et al., 1988). Total lean was defined as chemical protein x 3.56 (Ono et al., 1984).

Statistical analysis. Data were analyzed using SAS (1982), testing for interactions between groups of animals and criteria measured. Simple correlations and cumulative frequency comparisions between carcass and ultrasonic measurements were determined. Stepwise regression

procedures were used to determine the efficacy of using carcass measurements (actual or ultrasound) to estimate fat-free soft tissue or lean mass.

Results and Discussion

Means and standard errors for ultrasonic and carcass measurements are presented in table 1. For the carcass tissue components, coefficient of variation (CV) for total carcass fat had the greatest relative variation. Variation in slaughter weight may account for the variability in fat composition. Estimates of lean composition (fat-free soft tissue and total lean) had a CV of 12.6% and 12.0%, respectively. Among carcass measurements (actual and ultrasound), fat depth measurements were more variable than LMA. Ultrasonic fat depth estimates were less variable than fat depth measurements taken from the cold carcass. This would indicate that ultrasound was not sensitive to measuring the extremes. Last rib midline measurement had the greatest variability for actual and ultrasonic carcass measurements. Ultrasonic and actual carcass LMA were similar in variability.

Simple correlation coefficients of ultrasonic measurements with carcass measurements are shown in table 2. Ultrasonic estimates of fat depth at the dock correlated more poorly with its respective carcass measurement (r=.42) than any other trait. Fat depth at the

last rib (3/4 distance) achieved the highest correlation (r=.63). In contrast, Bass et al. (1982) reported correlation results of .87 to .95 for fat depth taken over the eye muscle at the 13th rib with two different ultrasound machines. It can be speculated that a higher correlation for fat depth at the last rib (3/4 location) was achieved because the measurement was taken off the midline where carcasses are split. Also, bounds for fat depth measurements via ultrasound are seemingly more distinct at the 3/4 location than on the midline of the animal. Thus, estimates should be more accurate.

Ultrasonic LMA was more highly correlated with carcass LMA than fat depth measurements. Moody et al. (1965), using a Branson A Scan, reported correlation coefficients of .52 to .63 between actual and ultrasonically estimated longissimus muscle measurements. These observations were similar to those reported in the present study where a correlation of .58 was obtained between carcass and ultrasonic LMA. This indicates that almost 34% of the variation of carcass LMA could be explained by the ultrasonic measurement.

Simple correlation coefficients of ultrasonic measurements with carcass tissue components are presented in table 3. Ultrasonic estimates of fat depth at the dock had a lower simple correlation with carcass tissue components than the other ultrasonic estimates. Ultrasonic

estimates of fat depth at the last rib (3/4 location) and LMA were more highly correlated with carcass tissue components than the other ultrasonic carcass measurements. Ultrasonic estimates of fat depth at the last rib (3/4 location) had the greatest correlation with total mass of fat (r=.62). Among fat depth estimates, the 3/4 location at the last rib was more highly correlated with total lean and fat-free soft tissue than the two fat depth estimates from the midline.

The correlation of ultrasonic LMA with total lean and fat-free soft tissue mass were similar to that of fat depth at the last rib (3/4 location). This indicates that ultrasonic measurements taken at the 3/4 location are better indicators for carcass tissue components than measurements taken on the midline. Possibly, there also could be shifting of fat along the median plane due to hanging of the carcass that would affect midline BF in a greater magnitude.

Actual carcass measurements were more highly correlated with carcass tissue components than ultrasonic live animal carcass measurements (table 4). In contrast to ultrasonic data, fat depth measurements from each of the three locations and carcass LMA were similarly correlated with tissue components. Carcass fat depth measurement at the dock provided the highest simple correlation coefficient with total mass of fat tissue (r=.68). This supports

previous observations that ultrasonic measurements at the midline are less accurate than those taken at the 3/4 location.

Since lambs have less BF and smaller LMA in comparison to swine and beef, any deviation from the actual would be greatly enhanced and simple correlation coefficients between carcass and ultrasonic BF and LMA could be misleading. Therefore, frequency distribution might enable a better understanding of the data. Frequency analysis of ultrasonic measurements in estimating the same carcass measurements is shown in table 5. Among fat depth measurements, last rib (3/4 location) estimated carcass fat depth within .40 cm. In contrast, midline fat depth measurements at the last rib and dock estimated carcass fat depth within .60 and .70 cm, respectively. Although it would appear that ultrasound did a better job of accounting for the depth measurements at the last rib (3/4 location), a deviation of 91% from the mean was observed. In contrast, ultrasonic measurement of BF at the dock accounted for its corresponding carcass measurement within a deviation of 58%. Ultrasound estimated LMA within .70 cm^2 of carcass LMA in which a deviation of 5% from the mean was observed. Moody et al. (1965) reported that the longissimus muscle area of 62%, 81%, 94%, 98% and 99% of the lambs were ultrasonically predicted within .64, 1.29, 1.93, 2.58 and 3.23 cm^2, respectively. The current study

demonstrates an improvement in estimating carcass longissimus muscle area via real-time ultrasound in comparison to the results reported by Moody et al. (1965). This could be attributed to equipment technology, ultrasound methodology and operator technique. Moody et al. (1965) used ultrasound depth points to form an outline estimation, whereas, the present study utilized an image area tracing. No data were found to support or disagree with the ultrasound fat depth estimation frequencies. Given the generally high percentage of estimation from ultrasound, it would seem that real-time ultrasound is a reliable method for carcass trait estimation. However, keeping in mind the comparatively small amount of fat depth on lambs, a small difference between actual and estimated fat depth measurements represents a substantial decrease in accuracy. Thus, fat depth measurements taken at the last rib (3/4 location) would be more appropriate than on midline at the dock or last rib.

Jenkins et al. (1988) reported on the estimation of fat-free soft tissue from carcass weight, composition and measurements using a subsample from the group of animals in this study. It was reported that these criteria can accurately estimate the mass of fat-free soft tissue of sheep. However, carcass weight was the most predominant criteria. In an attempt to estimate fat-free soft tissue and total lean for the entire data set, regression analysis

was implemented using actual and ultrasonic carcass measurements. Equations for predicting total lean and fat-free soft tissue derived from regression are shown in table 6. Coefficients of determination (R^2) for equations estimating fat-free soft tissue and total lean were .94 and .92 for actual carcass data and .89 and .88 for ultrasound data, respectively. Equations using live weight or carcass weight as the sole predictors for fat-free soft tissue and total lean provided coefficients of determination ranging from .86 to .91. Thus, weight (live or carcass) was the primary determinant for lean content of sheep. This is in agreement with observations reported by Jenkins et al. (1988). Kempster et al. (1982a) reported that dissection of sample joints is the best predictor of carcass composition.

For specific carcass measurements, real-time ultrasound using a Technicare 210DX seems to provide more accurate fat depth information if measurements are made at the last rib (3/4 location). Ultrasonic fat depth measurements at the midline appear more variable due to less distinct bounds for fat depth determination. Also, it appears that LMA can be estimated relatively accurately at the last rib (3/4 location) by real-time ultrasound. Carcass measurements (actual and ultrasound) can aid in improving predictability of fat-free soft tissue and lean mass. However, body weight (slaughter or cold carcass) is

the strongest predictor for these lean tissue characteristics.

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TABLE 1. MEANS AND STANDARD ERRORS FOR CARCASS TISSUE COMPONENTS, CARCASS MEASUREMENTS AND LIVE ANIMAL ULTRASONIC CARCASS ESTIMATES

Measurements	Means	S.D.[a]	C.V.[b]
Carcass tissue components, kg			
Total carcass water	12.9	1.60	12.6
Total carcass protein	3.6	.47	12.9
Total carcass fat	4.9	1.30	27.6
Total carcass ash	1.0	.16	16.2
Total lean[c]	13.0	1.70	12.0
Fat-free soft tissue[d]	16.5	2.10	12.6
Live weight, kg	46.2	5.7	12.3
Carcass measurements			
Cold carcass weight, kg	22.4	3.3	14.8
Dock fat depth, cm			
Midline	1.2	.47	38.1
Last rib fat depth, cm			
Midline	.59	.25	42.2
3/4 location	.44	.14	32.1
LMA (last rib), cm^2	14.6	2.1	14.1
Live animal ultrasonic carcass estimates			
dock fat depth, cm			
midline	1.2	.28	22.7
last rib fat depth, cm			
midline	.61	.16	26.2
3/4 location	.42	.11	25.4
LMA (last rib), cm^2	14.7	2.1	14.0

[a]Standard Deviation.
[b]Coefficient of Variation.
[c]Carcass protein x 3.56.
[d]Carcass water + carcass protein.

TABLE 2. SIMPLE CORRELATION COEFFICIENTS OF LIVE ANIMAL ULTRASOUND MEASUREMENTS WITH ACTUAL CARCASS MEASUREMENTS[a]

	Live Animal Ultrasound Measurements			
	Fat Depth, cm			
	Dock	Last Rib		LMA, cm^2
	Midline	Midline	3/4 Location	
Carcass Measurements				
Dock fat depth, cm				
Midline	.42	.30	.57	.40
Last rib fat depth, cm				
Midline	.36	.48	.51	.36
3/4 location	.25	.31	.63	.37
LMA (last rib), cm^2	.13	.23	.21	.58

[a]Correlations >.25 (P<.001); correlations >.21 (P<.01); correlations >.13 (P<.10).

TABLE 3. SIMPLE CORRELATION COEFFICIENTS OF LIVE ANIMAL ULTRASOUND MEASUREMENTS WITH CARCASS TISSUE COMPONENTS[a]

	Live Animal Ultrasound Measurements			
	Fat Depth, cm			
	Dock	Last Rib		LMA, cm^2
	Midline	Midline	3/4 Location	
Carcass tissue components, kg				
Total water	.18	.26	.48	.54
Total protein	.16	.26	.46	.53
Total fat	.41	.36	.62	.54
Total ash	.12	.14	.44	.46
Total lean	.16	.26	.46	.53
Fat-free soft tissue	.17	.26	.48	.54

[a]Correlations >.26 (P<.001); correlations >.14 (P<.10).

TABLE 4. SIMPLE CORRELATION COEFFICIENTS OF ACTUAL CARCASS MEASUREMENTS WITH CARCASS TISSUE COMPONENTS[a]

	Actual Carcass Measurements			
	Fat Depth, cm			
	Dock	Last Rib		LMA, cm^2
	Midline	Midline	3/4 Location	
Carcass tissue components, kg				
Total water	.51	.50	.50	.65
Total protein	.49	.49	.46	.64
Total fat	.68	.63	.58	.42
Total ash	.46	.34	.43	.50
Total lean	.49	.49	.46	.64
Fat-fee soft tissue	.51	.50	.50	.65

[a]Correlations >.34 (P<.001).

TABLE 5. FREQUENCY COMPARISON (PERCENT) OF LIVE ANIMAL ULTRASOUND CARCASS MEASUREMENTS TO ACTUAL CARCASS MEASUREMENTS

	Fat Depth, cm			
	Dock	Last Rib		LMA, cm^2
	Midline	Midline	3/4 Location	
Deviation (ultrasound - actual)				
±.10	63.0	25.3	69.1	60.5
±.20	71.0	59.9	93.2	61.1
±.30	77.8	82.1	98.8	64.2
±.40	80.2	96.3	100.0	67.9
±.50	85.2	99.4		68.5
±.60	89.5	100.0		71.0
±.70	100.0			100.0

TABLE 6. REGRESSION ANALYSIS OF CARCASS MEASUREMENTS (ACTUAL AND ULTRASOUND) ON FAT-FREE SOFT TISSUE AND LEAN MASS

	Fat-Free Soft Tissue, kg				Lean Mass, kg			
	Carcass		Ultrasound		Carcass		Ultrasound	
Model	B Value	P<	B Value	P<	B Value	P<	B Value	P<
Intercept	1.726		.837		1.267		.470	
Weight, kg								
Live	-		.347	.01	-		.279	.01
Carcass	.626	.01	-		.513	.01	-	
Dock fat depth, cm								
Midline	-.501	.01	-.720	.01	-.425	.01	-.645	.01
Last rib fat depth, cm								
Midline	-.516	.02	.609	.11	-.321	.12	.541	.10
3/4 loca.	-.063	.88	-.323	.64	-.636	.09	-.369	.53
LMA, cm^2	.118	.01	.021	.52	.084	.01	.018	.52
Regression coefficient, R^{2a}	.94 (.91)		.89 (.88)		.92 (.89)		.88 (.86)	

[a]Value within () represents regression coefficient for model containing weight as the sole predictor.

LIVE ANIMAL EVALUATION OF CARCASS TRAITS FOR SWINE AND SHEEP USING REAL-TIME ULTRASOUND

by

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ABSTRACT

Two experiments were conducted to evaluate real-time ultrasound (Technicare 210DX) as a viable method of estimating carcass measurements of swine and sheep. In experiment 1, the relationships of chilled carcass position (hanging vs. standing) with live animal ultrasonic estimations of swine carcass measurements were determined. A total of 75 crossbred market weight swine were ultrasonically measured to estimate backfat thickness (BF) and longissimus muscle area (LMA). Backfat measurements and LMA of the hanging chilled carcass were greater ($P<.02$) than either ultrasound or standing chilled carcass measurements. Standing chilled carcass LMA was less ($P<.01$) than the ultrasound LMA estimate. Cumulative frequency comparisons indicated that ultrasonic measurements were within .38 cm of hanging chilled carcass BF, 81.3% of the time while LMA was within 1.94 cm^2, 76% of the time. In swine, live animal ultrasonic estimates of carcass traits were more closely related to standing chilled carcass measurements than hanging chilled carcass measurements. In experiment 2, 162 ram lambs were ultrasonically measured for BF and LMA. After slaughter, all carcasses were ground to determine chemical composition. Ultrasonic BF measurements at the 3/4 location (3/4 distance over the LMA) were more closely correlated with actual carcass measurements ($r = .63$) than those taken

at the midline of the dock or last rib (r = .42 and .48, respectively). Ultrasonic LMA had a correlation of r = .58 to the actual LMA measurement and was within .70 cm^2 of LMA, 100% of the time. Carcass chemical composition was more closely correlated with actual carcass measurements than with ultrasonic measurements. Regression analysis indicated that body weight (live or chilled carcass) was the strongest predictor of fat-free soft tissue and total lean. In conclusion, real-time ultrasound can accurately predict BF and LMA measurements in swine and sheep.